A CONTRIBUTION TO THE PSYCHOLOGY OF RHYTHM.

By CHARLES H. SEARS, Fellow in Psychology, Clark University.

The paper here presented is a report of an experimental study of the time values given by competent players to the notes of several simple selections of music. When the musician begins his studies certain statements are made to him with regard to the relative values of notes. He is told that a half note should be given half the time of a whole note, a quarter note half the time of a half note, an eighth note half as much time as a quarter, and so on, and that a dot placed after a note adds one-half to its length. It is implied that all notes of the same kind should receive equal amounts of time unless a change of tempo is indicated, that a triplet should divide into three equal parts the time usually given to two like notes, that, except for purposes of expression, all measures are of the same length, etc. Toward fulfilling these requirements he strives with the metronome as an assistant. How far the trained musician accomplishes what the notes set before him indicate and what he sets out to do is an interesting question not only to the psychologist, but also to the musician. To answer this question for a few simple cases by direct measurement of the lengths of the notes played has been the aim of this study. The problem was suggested by Meumann, but so far as I know, no investigator has offered a contribution of facts gathered directly from the records of performers, although some work has been done in closely related fields as will presently be shown.

The work was undertaken at the suggestion of Dr. E. C. Sanford, to whom the writer most cordially acknowledges his obligation for help rendered throughout its progress.

RÉSUMÉ OF LITERATURE.

Because of the publication of Meumann's able working over of the whole subject of rhythm[1] it is natural to begin with him. We shall of course confine ourselves here to his discussion of rhythm in music, which he considers from the standpoints of the hearer, the player, and the composer.

In musical rhythm there appear not only the elements that

[1] Untersuchungen zur Psychologie und Æsthetik des Rhythmus, *Philosophische Studien*, Bd. X, S. 300.

are found in rhythmizing of uniform sounds and other simple rhythmical material, but also a number of new elements due to the special rhythmical material or rhythmizomenon in question. Working upon these the universal pleasure in tones and their combinations has brought about the peculiarly rich artistic development of musical rhythms. In a corresponding way the intellectual factors on which depend the perception of melody and harmony and the comparison of the different parts of musical compositions, as well as the play of association, memory, and fancy, are all more complicated and intense than with simple sounds. The same is true, of course, of the feelings and emotions excited. It is of interest to note, however, that in the perception of a rhythmical series of simple sounds the rhythm holds the first place, while in music it yields at least a co-ordinate place to the other distinctively musical factors.

But quite aside from this, the tones themselves do not behave like simple sounds. A low tone, for example, appears less intense than a high tone of the same objective intensity; the sudden breaking off of a quickly played tone series gives to the last tone a sort of accent, to be explained on the ground of sound summation. Tones are also possessed of real quantity, *i. e.*, they can be continued for a longer or shorter time, a thing that is not possible with simple noises; and with this belong also all the rhythmical effects arising from legato and staccato playing.

In treating rhythm from the standpoint of the player Meumann discusses the question of how the musician is able to produce the exact fractions of time intervals required by the notes on the written sheet. Experiments made upon subjects skilled in piano playing to determine how accurately intervals equal to certain fractional parts of given intervals could be produced when there were no artificial means of assistance showed that even good musicians were liable to considerable errors. A second test was made in relation to the observance of tempo. In this a good piano player was required to beat a rhythm first in accompaniment to a given standard rhythm and then alone. The intervals between the single strokes of the beating were 0.4 and 0.3 seconds. After the observer had beaten the rhythm thirty to forty times the standard rhythm was discontinued, while the subject kept on. As soon as the standard rhythm ceased the beating of the subject began to change. The tempo was first retarded, then the relative times of the intervals were altered, and gradually a change followed in the rhythm itself. These tests make it probable that the musician must have at his command in his ordinary playing some means or other of assistance. This means of assistance Meumann finds in a cer-

tain motor appreciation of duration; and the high degree of accuracy with which a musician can produce a required fraction of a standard interval when it is part of a musical score must be ascribed largely to this motor appreciation, *i. e.*, to the facility with which a rhythmic movement becomes automatic. In playing with both hands another means of control is possibly furnished by the aid one hand may give to the other. For example, when the right hand plays a complicated passage, the left supported by its automatism can preserve the original rhythm, marking for the right hand the essential points of each measure. Counting introduces still another motor procedure, which becoming quickly automatic acts as a steadying influence. The movements of the director have a similar result. The effect of all this automatism is to unburden the attention so that it may concentrate itself upon the musical purport of the tones.

To Binet and Courtier[1] belongs the credit of having recorded by the graphic method the fingering of pianists with indications of the force and time relations of the strokes and of suggesting a number of problems that can be solved in this way. Their results may be summarized in part as follows: The fingers of pianists are unequal in strength and lack independence. This follows naturally from the anatomical structure of the hand. In the execution of trills played with the index and middle fingers the irregularity of the movements, as shown by tracings, is marked. However, a high degree of regularity results from practice. In playing the piano notes are frequently slurred or tied. These effects may arise from a variety of conditions, three of which are: "1. In the movements of the last fingers, especially of the third and fourth. 2. In the state of fatigue; the slurring or tying of notes is a rest for the sluggish or fatigued hand. 3. In movements of great rapidity." The movements of the thumb vary in facility of execution; those coming after the third and fourth fingers are more difficult to perform than those that follow the first and second. The notes preceding the thumb movements have a diminished intensity. In slow playing the notes are rarely tied or slurred, and both the notes and intervals are regular. But as the rate of movement increases the irregularities become more and more apparent. A renowned musician in playing five successive notes was found to retard the interval between any two notes 0.01 of a second. In ten successive trials it was observed that the value of the intervals always increased as they advanced up the scale, the average increase varying from 0.01 to 0.015

[1] Recherches Graphiques sur la Musique, L'Année Psychologique, 1895, p. 201.

of a second. In relation to the accentuation of single notes these investigators found that a tendency exists—" 1. to separate the accented note from the preceding note, 2. to tie or slur the accented note to the following note, 3. to increase the length of the note accented as if this increase were equivalent to an increase in intensity, 4. to increase, especially in rapid playing, the intensity of the notes which follow the note accented."

Ebhardt has made two contributions to the psychology of rhythm and tempo[1]—one on the influence of accent on the relations in musical rhythm and the other on the influence of accompaniment on the tempo. In order to discover the effect of rhythmic accent on temporal relations he first conducted a course of free tapping experiments consisting of both accented and unaccented series of sounds. He found that absence of accent was attended by a want of uniformity in the time relations of the members, but that there was no constant increase or decrease of the times in the course of the series. His results show that the greatest uniformity of movement lies approximately within that range of rates within which Vierodt[2] found the greatest exactness of judgments, that of 0.4-0.7 seconds. In the case of series with accent, experiments were made upon the different forms of bipartite and of tripartite rhythms. In all of these forms the variations of the members from one another appeared far greater than in the unaccented series, *i. e.*, the errors were the largest in the accented series. The conclusions drawn from these experiments are that a rhythmic accent exerts a disturbing influence on the keeping of time, that it is a source of constant error, and that in the great majority of cases the accent gives rise to a lengthening of the time of the accented member. There is much evidence for the opinion that accent causes not a shortening of the preceding but a lengthening of the subsequent member. In two forms of the tripartite rhythm—the one in which the second member and the one in which the last member receives the accent—when the repetitions were somewhat lengthy, the accented member showed a tendency to change gradually its order in the group. In the production of tripartite rhythms the groups were separated into unities by means of an inserted pause. This was the most easily done and the most distinctly marked in rapid tapping. As the movements became slower this separation of the groups gradually faded out.

The investigations on free tapping were followed by experi-

[1] Zwei Beiträge zur Psychologie des Rhythmus und des Tempo, *Zeitschrift für Psychologie und Physiologie der Sinnesorgane*, Bd. XVIII, p. 99.

[2] Untersuchungen über den Zeitsinn, Tübingen, 1868.

ments in which simple tone series were played on the piano. The use of the piano brought in certain changes, such as the appearance of tones in the place of noises, the use of not only one but of all the fingers, etc. The series of experiments corresponded exactly to that used in the investigations on free tapping. With the exception that the variations were somewhat smaller the results in all cases showed the same general characteristics as in the previous tests. Neither in the tapping nor in the playing of simple rhythms did the variations all lie in the same direction—some were positive and some were negative.

The experiments made for the purpose of finding out the effect of an accompaniment on the tempo consisted in having a certain portion of a piece of music played with and without accompaniment, and in every case taking the playing-time with a fifth of a second watch. In playing a passage repeatedly it was found that the variation in the amount of time required for the different performances rarely exceeded 0.2 to 0.3 seconds on an average. In playing 19 selections, nine of which were given 20 trials each, seven, 16 trials, and three, 10 trials, less time was required for the performing of each selection when played with accompaniment than when played without acccompaniment. Ebhardt explains this result on the ground that feeling enters in as the determining factor of tempo; an accompaniment increases the emotional effect. A number of the selections were also played upon a dumb clavier. In every case more time was taken than had been required for playing the same pieces without accompaniment. This retardation is attributed to two causes,— an increase of psychical activity, which consumes an excessive amount of time, and to a retardation in the rise of the feelings which do not come forth so quickly as with the full tonal sensations. The retardation is not noticed for the reason that consciousness has no means of perceiving absolute rate.

In a carefully conducted set of experiments Shaw and Wrinch[1] sought to determine by means of tapping movements "the degree of accuracy that obtains in the reproduction of complex rhythmically arranged groups of intervals of unequal length." From their results it appears that the average mean variation, when expressed as a percentage for all the reproduced groups, was only a fraction of one per cent. greater than it was for a series of simple intervals, and that the average mean variation of the complete groups was quite uniform, and smaller than it was for the individual intervals of the more complicated groups. In the repeated reproductions of a series

[1] University of Toronto Studies, Psychological Series, 1899, p. 44 ff.

the different lengths of the intervals held to one another within certain limits a comparatively uniform relation—there seeming to be a tendency to increase rather than lessen the accuracy of their reproduction as the number of judgments became larger. The length of the intervals was not affected by the differences in the pitch of the tones forming the melody.

In the records of ten intervals from the "Boccaccio March" there appeared four distinct types of notes, but their lengths did not hold to one another "the definite relation of one, a half, a fourth, and an eighth, as in written musical compositions." This leads the investigators to affirm that while their experiments yield nothing conclusive upon the subject yet they do indicate that "the relative length of musical notes in the production of a true musician is not in the exact ratio of one to a half, a quarter, an eighth, and so on."

General Summary of Literature. While the investigations cited have not been reports of the time values given by practiced musicians to the notes of complete musical compositions, yet they have relation to intervals and groups of intervals occurring in musical rhythms. A brief summary of the results that are important in connection with the present investigation may be made in the following statements: Musical rhythms contain elements additional to those found in simple rhythms and are therefore more complex. In music rhythm does not hold the primary place, but a co-ordinate place with other distinctively musical factors. Irregularity of movements in playing results from peculiarities due largely to the structure of the hand. Much of this irregularity may be overcome by practice. Irregularity is the most marked in rapid playing which leads to the expectation that in the production of a piece of music those measures that contain many notes will possess greater variations than those containing only two or three. Pitch of tones has no effect on the relative length of intervals. For simple intervals without accent the greatest exactness of execution is between 0.4-0.7 seconds. Accent, increasing the irregularity of the time relations in the group, is the source of a constant error. Usually the accented member is lengthened. In the production of complicated groups of intervals of unequal length the judgments are somewhat less uniform than for simple intervals, the individual intervals of the groups showing a greater variation than the complete groups. The time relations for the different reproductions of repeated groups of intervals show a tendency to remain quite constant. When a selection is played repeatedly there is little variation in the total time required (Ebhardt). The degree of accuracy which a musician secures in the production of intervals in the relation of one, a half, a quarter, and so on, is to be attributed

to the facility with which rhythmic movements become automatic (Meumann). An accompaniment influences the tempo by decreasing the total time. In the rendering of a piece of music musicians probably do not produce the tones in the exact ratio denoted by the written notes (Shaw and Wrinch).

Preliminary Experiments.

The Time Intervals in Selections Played by a Music Box. The purpose of this preliminary investigation was to discover the nature and extent of the variations in the duration of the tones in music produced in this very mechanical way. The music box used was of Swiss make, of medium size, and played ten pieces. The method employed was to count the number of half turns made by the fan regulator between the sounding of the individual tones when the mechanism was made to move very slowly. To facilitate this labor a mechanical counter was used which recorded each half turn of the regulator as it was allowed to take place. The number of half turns in the duration of the tones in the pieces studied were counted in this way three times. The counts for the same note sometimes varied one or two half turns in the different counts, but generally not at all.

Two pieces were thus measured, "The Blue Alsatian Mountains" and "La Gitana Waltz." Both are written in ¾ time. The music box in each case played only the principal theme to which, however, certain notes not found in the piano score were added. In reckoning up the results these variations of score have not been considered. The results are given below in half turns of the fan regulator, a half turn being equal approximately to 0.0074 of a second.

The part of "The Blue Alsatian Mountains" played by the music box contained 27 measures. The average length of the measure was 89.30 with M. V. of 2.28. The greatest difference between any two consecutive measures was 10. The average irregularity[1] was 2.73. In the part of "La Gitana Waltz" played there were 16 measures. Their average length was 78.13 with M. V. of 2.27. The greatest difference between any two consecutive measures was 9. The average irregularity was 3.73.

The variation in the notes of the same kind is also well marked. The average length of the notes of the different de-

[1] The "average irregularity" is found by averaging the differences *between the successive measures*, and gives a result somewhat larger than the mean variation, found in the usual way by averaging the variations of the individual measures *from their mean*. The "average irregularity" has been used here and below, because it is believed to be a better index of the particular sort of irregularity in question.

nominations is as follows: In "The Blue Alsatian Mountains:" quarter note, 30.73 with M. V. of 1.83; half note, 58.42 with M. V. of 1.42; dotted half note, 86.83 with M. V. of 1.83. In this piece there was no more than one note of any of the other denominations. "La Gitana Waltz:" quarter note, 25.67 with M. V. of 1.44; eighth note, 14.25 with M. V. of 2.25; dotted quarter note, 34.25 with M. V. of 1.12; half note, 54.0 with M. V. of 2.0; dotted half note, 78.20 with M. V. of 2.64. It is interesting to observe that in "The Blue Alsatian Mountains" the notes of the denominations other than a quarter note are shorter than their proportionate value as measured by the quarter note, and that with the exception of the dotted quarter the reverse appears true in "La Gitana Waltz." Whether this is purely accidental or the result of design cannot at present be determined.

As regards the relative length of accented and unaccented notes nothing certain appears. Comparing the average accented note with the average unaccented note there is found in both pieces a very slight difference in favor of the unaccented note, but the probable error in both cases is so large that the difference has no significance.

The data which this study of the music box presents toward the solution of our main problem is not very great; but, since its selections may be supposed to be rendered in reasonably good time, it does give some indication of the extent of variation in the length of measures and notes that will ordinarily pass unobserved, and furnishes, as a very "mechanical" means of producing music, an interesting basis of comparison with the performers whose playing is next to be considered.

Time Relations in the Playing of Musicians.

Apparatus, Method, and Subjects. The instrument used was a small reed organ manufactured by Messrs. Moore and Moore, of London, and tuned according to the directions of Ellis for use as a Harmonical.[1] For rhythm experiments the organ has one important point of difference from the piano. Upon it the intensity of the tone does not vary with the intensity of the finger stroke.

It was necessary that the recording portion of the apparatus should meet the following conditions: 1. It should be free from all disturbing noises; 2. It must not modify the action of the instrument so as to interfere with the technic of the playing; 3. It should register accurately and return to its original position the instant the sound of the tone has ceased. Elec-

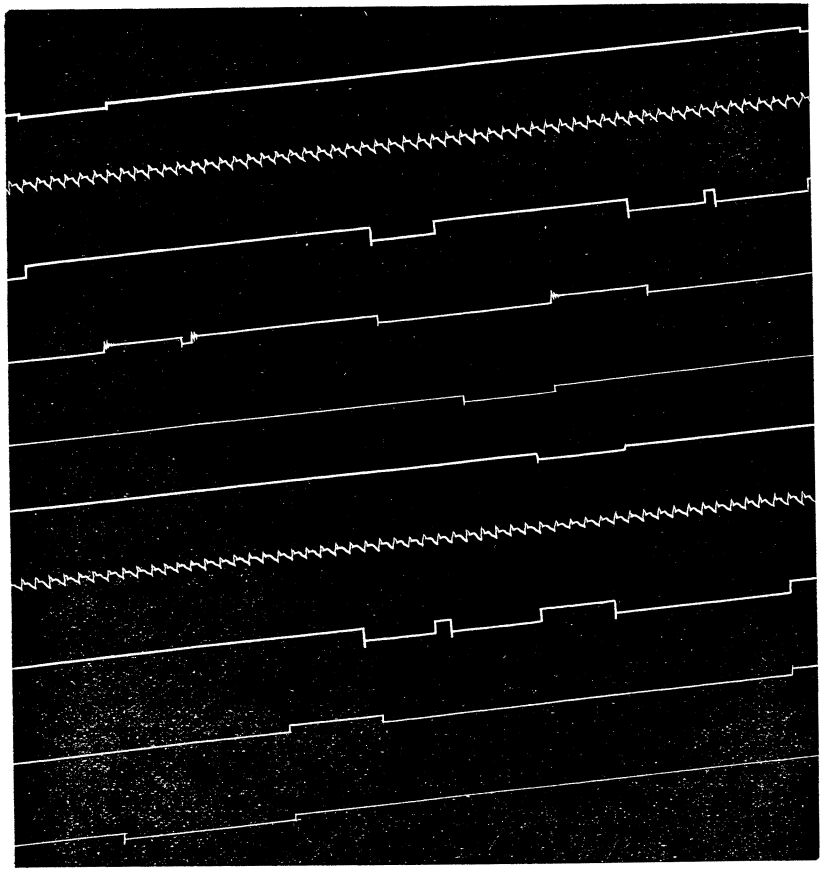
[1] *Cf.* Ellis's translation of Hemholtz's Sensations of Tone, Second Edition, p. 466.

trical registration by means of mercury contacts was employed, the records being finally traced upon the smoked surface of a kymograph drum. The contacts were arranged as follows: Steel pins were passed through the keys about two and a half inches from their back ends. Beneath the keys at the back of the instrument was placed a series of mercury cups in such a way that when a key was depressed the lower end of its steel pin would dip into the mercury and make an electrical contact. To the upper end of the pins were attached wires which led to brass buttons fastened to the back of the organ frame. From these buttons other wires led to four writing magnets, three Deprez and one Pfeil signal, which wrote on the smoked drum. It is obvious that with so small a number of writing magnets it would be impossible to record all the notes of all the parts in a harmonized piece of music. It was therefore decided to record only the upper or soprano part, that being the leading part and the one most likely to show the general time relations which were the chief matter of investigation. In order to secure even this with so few inscribing points it was necessary to arrange the wiring so that no two consecutive notes should fall to the same point. This was worked out for each selection by previous study, and wire connections were especially arranged each time for each selection by attaching or detaching from the brass buttons above mentioned. As the apparatus was finally arranged three notes could be assigned to each magnet, though as a general thing this was not required. An example will make the matter clearer. In one of the pieces used there are ten different tones in the soprano part, viz., d', $e'\flat$, f', g', $a'\flat$, a', $b'\flat$, c'', d'', $e''\flat$. The keys corresponding to these tones were distributed to the four writing points as follows: To point 1. $e'\flat$, a', $e''\flat$; to point 2. d', g', d''; to point 3. $b'\flat$, f'; to point 4. $a'\flat$, c''. By reference to the selection (No. 254, below) it will readily be observed that in its execution the keys connected with the same point were never depressed consecutively. Thus there was between any two functionings of a single point one or more records made by one or more of the others. By this means each note had a distinct place in the record, and thus the reading of the record was facilitated.

In reading the kymograms the notes on the different lines were read in the order in which they occurred in the selection played. For example, in the specimen record here reproduced the transitions from one line to another were made as follows: 1 to 2, 2 to 3 (two notes), 3 to 4, 4 to 3, 3 to 2, etc.

In addition to the four points already mentioned a fifth wrote simultaneously a time-line in tenths of a second from which values in hundredths could be read by estimation.

Before each subject began playing such adjustments were



carefully made as should make it certain that the recording of each note would begin at the instant the key was sufficiently depressed to produce the first sound of the tone.

It was thought that the usual way of blowing the organ with the feet might act as a disturbing factor in that it would itself require a certain rhythmic movement or possibly a partial division of attention, either of which might interfere with the subject's rendition of the music to be played. To avoid such effects the organ was arranged for hand blowing by an attendant. This method obviated the difficulties mentioned, but proved not absolutely noiseless. The subjects, however, reported themselves as uninfluenced by this noise. Care was taken to work the bellows irregularly so as to prevent the sounds from furnishing any regular rhythmic effects.

Screens hid from the subject's view all the recording apparatus and as far as possible the movements of the attendant who worked the bellows.

The music selected for the investigation consisted of church hymns. Five selections were made, each of which contains some characteristic feature peculiar to itself. (See the scores in connection with the tables at the end of the article.) In most cases the subjects played the air only, and three records were taken successively of each hymn. In case of two of the hymns, all four parts were also played, the air alone being recorded. In these cases two records only were taken.

Before taking any records the subject had ample opportunity to familiarize himself with the action of the organ and the selections to be played. He was given perfect freedom to play in his own natural way. Records were taken from four different persons, all practiced musicians. B, M, and W were church organists. B and M were professional musicians of considerable local prominence, teachers and chorus directors. S, the wife of the writer, has been a music teacher and a church organist, but at the time of the experiment was somewhat "out of practice."

The first examination of the records disclosed the fact that very rarely did one tone begin at the instant that the preceding one had come to an end, but that one tone usually began before the preceding one had ceased. This occasioned what may be termed an "overlapping" of tones. Sometimes, however, an interval occurred between two successive tones instead of an overlap. In counting up the records it was therefore essential to report two things, namely, (1) the time during which the note sounded, and (2) the length of the overlap or interval by which it was connected with the preceding and succeeding notes. In the final reckoning up of the lengths of the notes it is necessary to take these overlaps and intervals into account, and this has been done throughout on the assumption that each note was intended by the player to last until the following note was struck and no longer. The overlap has therefore been subtracted from the full time of the preceding note in every case in which it appeared and the interval added when it occurred.

RESULTS OF TESTS IN WHICH THE AIR ALONE WAS PLAYED.

General Rate. The time occupied in playing the whole hymn or selection is of course a slightly variable one. It not only varies for different subjects in playing the same selection, but also for the same subject in playing the same selection at different times. The results below give in seconds the average

time of the three trials for the different subjects and the different hymns.[1]

TABLE I.

Showing in seconds the general rate when the air alone was played.

	SUBJECTS.			
Hymn.	S	B	M	W
18	28.20	31.33	23.83	23.57
53	18.32	18.75	18.41	16.83
254	38.87	36.54	——	——
464	33.20	35.01	21.26	——
516	——	——	41.39	38.09

The greatest difference between any two subjects for hymn 18 is 7.76; for hymn 53, 1.92; for hymn 254, 2.33; for hymn 464, 13.75; and for hymn 516, 3.3. In a comparison of the average times of the different subjects for playing the different selections it appears that it is a general characteristic of W to play at a faster rate, and of B to play at a slower rate than either of the others. Beginning with the one having the least rapid rate the subjects stand in the following order: B, S, M, W. In hymn 464 no satisfactory explanation can be made for the great difference 13.75. M in all three trials played this special selection at an unusually rapid rate.

The greatest difference existing between any two consecutive trials by the same subject and with the same selection is as follows:

TABLE II.

Showing the greatest difference between any two successive trials.

	SUBJECTS.			
Hymn.	S	B	M	W
18	.17	2.16	1.35	.79.
53	.38	2.21	2.73	.82
254	1.17	2.74	——	——
464	.54	1.87	1.03	——
516	——	——	1.27	.[71][2]

[1] For hymns 254 and 516 records were taken from two subjects only. In the tracings for W., hymn 464, the relations of the writing points at starting could not be determined with sufficient exactness, and the records were rejected.

[2] One of W's records with hymn 516 could not be used in this case.

Subject S in the case of hymn 464 and subject M in the case of hymn 516 performed one of the trials on a different day from that on which the other two were played, with a difference in time of 2.78 for S and 3.14 for M.

On account of the size of the drum of the kymograph only one trial could be recorded at a time for most of the selections. Thus it was necessary before each repetition to pause long enough to substitute another drum or to apply and smoke a new paper. In the case of selection 53, however, it was possible to make two records on the same drum, and there was thus only a brief pause between each two of them, with a pause of the usual length between the twos. On comparison of the length of the three trials in the case of the other hymns it was found that the first trial was the shortest 7 times out of 9; the third trial was the longest 4 times out of 7; and the second trial took more time than the first trial, but less time than the third 7 times out of 10.[1]

In hymn 53, where two records were taken with practically no intervening pause, every subject required less time for the first trial than for the second. In the case of B a second set was counted in which the reverse appears true, but the combined time expressed by the two records in this set exceeded that of the first set by 4.88. These facts would indicate, so far as they have a general significance, that a musician in playing a selection a second time tends to play it at a slower rate than he did the first time, provided no pause or only a short one lies between the original performance and the repetition. This result is the opposite of that found by Triplett and Sanford[2] for the recitation of nursery rhymes.

The differences appearing in Tables I and II are of such a nature as to elude explanation except as "personal differences," though a fuller study of the individual subjects would probably account for some of them.

Bach and his school tried to establish an absolute standard of rate, taking as a typical measure a group of four quarter notes, one to every pulse beat. To this measure the time values of all others bore a constant ratio.[3] But such a system as this, if strictly carried out, would be as apt to increase as to decrease such irregularities as are here under consideration; and modern musicians having set aside the normal pulse beat, find their

[1] There are not the same number of trials throughout for the reason that in one instance one subject gave the first and third trials the same amount of time, and that in two other instances one of the records was taken on a different day from that of the other two.

[2] *American Journal of Psychology*, Vol. XII, pp. 376, 382.

[3] Kufferath: Rhythm, Melody and Harmony, *Music*, XVII, 37 f.

absolute standard in the metronome or in the number of quarter notes per minute.

The Measures.

The measures vary not only with the general rate but among themselves for the same subject and the same selection. The following table gives the average time of the measures in the different selections. Here and throughout the remaining part of the work partial measures at the beginning and at the end of a selection are not taken into account; and the last full measure, owing to its being affected by the approaching close of the piece, is also excluded.

TABLE III.

Showing in seconds the average length of the measures.

	SUBJECTS.			
Hymn.	S	B	M	W
18	3.43	3.65[1]	2.94	2.81
53	3.08	3.16	3.07	2.66
254	2.39	2.23	——	——
464	2.07	2.18	1.34	——
516	——	——	1.75	1.59

Examining the measures as they appear in the individual trials the greatest difference between any two successive measures may be found. These differences are stated in the following table. The figures in smaller type below the differences represent the value of the differences as a percentage of the corresponding average measure in the preceding table.

From these amounts the differences of successive measures fall away to zero. In order to indicate the average amount of variation we may calculate the "average irregularity as explained above." The results are given in Table V.

There is no clearly evident order in the variation of the measures except a retardation when nearing the end of the

[1] Average of six measures. In every trial B made a disproportionately long interval (pause) at the end of the first half of the selection. If this interval, which amounts to .36 sec. is added to the preceding note, as has been done in the case of all other intervals, the time of the full measure becomes 4.65 seconds. If this measure is taken into account the average length of a measure for B with this hymn becomes 3.80 instead of 3.65 seconds.

TABLE IV.

Showing in seconds the greatest difference between any two successive measures in the individual trials.

	SUBJECTS.			
Hymn.	S	B	M	W
18	.25 7.3	.29 7.9	.18 6.1	.18 6.4
53	.23 7.4	.31 9.8	.12 3.9	.27 10.2
254	.27 11.3	.17 7.6	——	——
464	.24 11.6	.25 11.5	.17 12.7	——
516	——	——	.23 13.1	.39 24.5

TABLE V.

Showing average irregularity.

	SUBJECTS.			
Hymn.	S	B	M	W
18	.096	.128	.072	.073
53	.066	.098	.082	.140
254	.095	.058	——	——
464	.099	.057	.053	——
516	——	——	.088	.174

selection. In the final averages the last full measure is longer than the next to the last 12 times out of 15; it is equal once and smaller twice. The next to the last is larger than the one preceding it 9 times, equal twice, and smaller 4 times out of 15. If the measures in the separate trials are examined then the last full measure is longer than the next to the last 35 times out of 47, equal 3 times and smaller 9 times; and the next to the last is larger than the one preceding it 29 times, equal 3 times and smaller 15 times.

The general irregularity seems to be greater in the last half of the selections, but this is due chiefly, if not entirely, to the terminal retardation already mentioned. As regards other possible relations the most that can be said is that in some of the hymns there is a suggestion of a systematic arrangement in the length of the measures within the groups allotted to the lines of the hymn or within the corresponding musical phrases.

This takes the form in two of the hymns roughly of a slowing from first to last within the line or phrase group and in a third of a progressive quickening. In the other two cases no such relation can be made out. One of the latter was played from a manuscript score, and the words were unknown to part of the subjects. The evidence furnished by the tracings for such an accommodation of the music to the words is too slight to warrant the assertion that it exists, but, nevertheless, such a relation is not impossible.

The Notes.

Since the time of the measures is variable, it follows that the time of their component parts must also vary. Such variations are found not only in the different measures, but even in the same measure. The variation of the notes of the same denomination in different portions of the same selection need not be discussed here. That they do differ and how widely may be seen in the tables at the end of the article, where the average time values are given together with the musical score. The table below gives the average length of the various kinds of notes irrespective of their place in the selection.

TABLE VI.

Showing in hundredths of a second the average length of notes.

HYMN.	SUBJECT.	WHOLE.	DOTTED HALF.	HALF.	DOTTED QUARTER	QUARTER	EIGHTH.
18	S			87		41	
	B			92		44	
	M			74		37	
	W			71		35	
53	S			111	80	51	22
	B			109	79	53	23
	M			101	76	52	24
	W			96	67	45	16
254	S			123		59	
	B			110		56	
464	S		156			51	
	B		162			55	
	M		100			34	
516	M	174		86	70	44	22
	W	136		82	66	41	20

If the quarter note is taken as the basis of comparison it appears that the relative length of the other kinds of notes differs for the different subjects, and with the exception of S for the same subject in different selections. They are sometimes too

long and sometimes too short. All the subjects make the eighth notes too short, sometimes very much too short, except M in hymn 516, where the ratio is exact. S, also without exception, makes the notes of higher denomination than the quarter too large. B, M, and W are less uniform than S, varying from the standard in both directions. Another method of testing the same matter—applicable in certain cases—consists in finding the number of instances in which the notes of other denominations are proportionately longer or shorter than the average quarter note of the same measure. The results of such a comparison are, however, with few exceptions in agreement with those just given.

Special Cases.

Triplets. In hymn 18 there are two triplets, one in the second full measure and the other in the last. Both take the place of unaccented half notes. All the subjects but M make the first triplet shorter than the average unaccented note, and all but S make the second longer. This last, however, is probably due to the approaching close of the piece. If each triplet is compared with the unaccented note of its own measure the results are conflicting, and the chances seem about equal that the triplet will be too short or too long.

Turning to the individual notes of the triplet there is a tendency to give more time to the second note than to the first, and more to the third than to the second. In the average results the second note in both triplets is made longer than the first by S, M, and W. This is not true of B, however, in either triplet. If the separate trials are examined, there are six possible chances for each subject to make the second note of the triplet longer than the first. S, M, and W do so 5 times, and B 3 times of the six. The last note of the triplet is made the longest of the group by all the subjects, and in all cases with the exception of M in the case of the last triplet where there are two trials in which this is not true. Thus while the tendency is slight to make the second note longer than the first, it is very strong to make the last longer than either of the others.

Dotted Eighth and Sixteenth Notes. The combination of dotted eighth and sixteenth notes in the second measure of the measures from hymn 53 presents an interesting study. All the subjects without exception made the whole measure very slightly longer than the ones that precede and follow it, though with such slight differences that the relation may be only accidental. Three of the subjects gave more time to the half of the measure containing the dotted eighths and sixteenths than to the first half. S made it 0.02 sec., B 0.08 sec., and M 0.03 sec.

greater, while W made it 0.01 sec. less. A comparison of the component parts of the last half of the measure with the average of the quarter notes in the first half of the measure shows a great lack of uniformity in the duration of both the dotted eighths and their combination with the sixteenth notes. On the other hand the sixteenth notes with two exceptions are all of too long duration. B and M each make the first sixteenth too short, but in both of these cases the dotted eighth with which the sixteenth is coupled is unduly long—longer than its proportionate part of the standard unit of measure, and longer than any of the other dotted eighths.

Accent.

Meumann, in his experiments upon rhythms executed in bare taps, found a marked tendency to hold the tap corresponding to the accented beat of the measure (*op. cit.*, p. 321), and Ebhardt reports something similar (*op. cit.*, pp. 126 and 127). The question naturally arises whether such a tendency appears in the musical records under discussion. Not all the selections contain such combinations of notes as to make determinations possible, but the number is sufficient to throw some light upon the question.

TABLE VII.

Showing in fractions of a second the average length of the accented and unaccented notes.

Hymn.	No. of Usable Notes.		Subject.	Average Accented.	Probable Error.	Average Unaccented.	Probable Error.
	Accented.	Unaccent'd.					
18	13	10	S	.893	.0053	.836	.011
			B	.926	.0063	.901	.011
			M	.744	.0043	.711	.0065
			W	.715	.0051	.690	.0063
254	22	22	S	.589	.0028	.591	.0040
			B	.557	.0036	.559	.0025
516	27	25	M	.454	.0033	.427	.0023
			W	.418	.0041	.404	.0048

Table VII gives the results for the trials in which the air only was played. In hymn 18 when all parts were played (see p. 38 above and the tables at the end of the article) there were 20 notes whose accent could be determined. 12 of these occupied positions of accent. The average duration of the accented notes was .898 sec., with a probable error of .0078, and that of the unaccented notes was .858 sec., with a probable error of .0099. These figures from the tests with all parts

are for subject S alone. For reasons that will be given later no results could be computed for the tests with other subjects.

Comparing the lengths of the average accented and unaccented notes for each subject in the different selections it will be noted that in hymns 18 and 516 the duration of the accented note in every instance exceeded that of the unaccented one. Hymn 254, on the contrary, does not show this characteristic. Neither in the case of S nor of B is there any more than a small fraction of a thousandth of a second one way or the other. Accent does not seem to have affected the relative duration of the notes in this hymn at all.

The above computations were made upon note values corrected for the length of time the preceding tone overlapped the succeeding one (*cf.* p. 38). For purposes of comparison the average accented and unaccented notes have been calculated without this correction. This was done for all the subjects and for all three selections. The results, although showing the same general characteristics are far less uniform than before, the greater variation being caused by the great differences in the lengths of the overlaps. In hymn 254, however, there appears a slight tendency in the case of both subjects, S and B, to lengthen the accented notes which was not the case, as has already been noted, when the overlaps were subtracted in the usual way.

The relative lengths of the accented and unaccented notes may also be studied by counting in the individual records the number of times the accented note exceeds in length the unaccented note immediately following it. The results are expressed in tabular form in Table VIII, the count being made upon the corrected notes used in Table VII.

If the results for all the subjects are combined there are in hymn 18 one hundred sixty-eight accented notes. Of these 116 are made longer, 6 equal, and 46 shorter than the following unaccented note. Hymn 53 has 72 usable accented notes, of which 38 are longer, 6 equal and 28 shorter. Hymn 254 has 132 accented notes, with 60 longer (18 of which occur at the end of the stanza lines), 15 equal, and 57 shorter. Hymn 464 has 90 usable accented notes, with 43 longer, 11 equal, and 36 shorter. Hymn 516 has 162 accented notes, of which 99 are longer, 11 equal, and 52 are shorter than the following note.

It is evident from the foregoing that accented notes are often longer than unaccented notes of the same denomination, but it is also evident that this tendency is not present in all cases and with all players. One may conjecture that it will appear most prominently in pieces, *e. g.*, marches and processionals, which require a strong marking of the rhythm, and will be more or less completely absent in pieces of a more flowing character.

TABLE VIII.

Showing relation of accented notes to the immediately following unaccented notes.

HYMN.	SUBJECT.	WHOLE NUMBER OF ACCENTED NOTES.	NUMBER LONGER.	NUMBER EQUAL.	NUMBER SHORTER.
18	S	42	29	2	11
	B		30	—	12
	M		30	2	10
	W		27	2	13
53	S	18	12	1	5
	B		8	—	10
	M		8	2	8
	W		10	3	5
254	S	66	29	8	29
	B		31	7	28
464	S	30	15	4	11
	B		18	2	10
	M		10	5	15
516	M	81	54	5	22
	W		45	6	30

Intervals and Overlaps.

As already explained on p. 38 there were found in the original tracings many instances in which one note ceased to sound before the next began, and many also in which the first overran the beginning of the second. The first I have called "intervals," the second "overlaps." Both deserve a little fuller consideration.

Intervals. The intervals are of two sorts: 1. Those which occur between consecutive notes on the same degree of the staff, involving of course the same digital of the organ. 2. Those which occur between successive notes on different degrees of the staff. The first is much the larger class. Where two notes occur in immediate succession on the same degree of the staff a minute pause is necessary in order to make the two distinct. Such pauses occurred with all the subjects and in equal number.[1] The number of intervals of the second kind varies for the different subjects and for the different repetitions of the selections.

[1] This, however, would not be true when playing all parts of the selection, for organists quite generally keep the key depressed during the whole time denoted by the several notes on the same degree of the staff.

TABLE IX.

Showing the number and average length of intervals of the first kind. Unit 1 second.

HYMN.	NUMBER OF INTERVALS.	AVERAGE LENGTH.			
		S	B	M	W
18	24	.084	.102	.071	.081
53	18	.131	.111	.050	.079
254	18	.138	.113	——	——
464	24	.078	.095	.099	——
516	54	——	——	.608	.088

TABLE X.

Showing the number and average length of intervals of the second kind. Unit 1 second.

HYMN.	S		B		M		W	
	NUMBER.	AVERAGE LENGTH.	NUMBER.	AVERAGE LENGTH.	NUMBER.	AVERAGE LENGTH.	NUMBER.	AVERAGE LENGTH.
18	13	.137	3	.017	0	0	11	.032
53	11	.128	3	.023	0	0	6	.015
254	15	.178	4	.057	—	—	—	——
464	7	.208	0	0	0	0	—	——
516	—	——	—	——	7	.023	14	.029

It is to be noted that the length of an interval does not depend upon the kind of notes in which the selection is written—that the intervals are no longer in a piece written in half notes than they are in one written in quarter notes. Subject S in most cases made intervals of the second sort to correspond with the pauses at the end of the verse lines, but this is characteristic of S alone.[1] These intervals are usually much longer than those of the first kind, and explain the great length of the intervals of S, in Table X. The other intervals of the second sort are short, and are probably accidental as they do not occur at corresponding places in the different trials. The characteristic of S in making intervals at the end of verse lines does not, however, seem to have affected correspondingly the time of the measures in which they occur, and this is one of the facts that make it uncertain whether the words really modified the time of the measures as explained above.

[1] There is one exception to this statement. B in hymn 18, as already explained, p 41, made an exceptionally long interval at the end of the second verse line. Its average for the three trials is .363 sec.

Intervals have something of the nature of rests; they have little effect in increasing the length of a measure. The note just preceding the interval is shortened, and to be equivalent to a full note it must have added to it the value of the interval, as has been done for all the preceding tables.

Overlaps. Consecutive notes on different degrees of the staff are generally overlapped. This is probably done in the interest of smoothness. It is nearly impossible to make the end of the one tone and the beginning of the next exactly synchronous; and, if it were, the effect would very likely be less flowing than with the overlaps. Intervals on the other hand would give a staccato effect not desirable without special reason.

The overlaps are by no means uniform. Perhaps all that can be said is that if an overlap is large in one trial of any subject it is likely to be found so in the rest. The same two notes, however, may not overlap to the same extent even in different parts of the same selection. For instance, in hymn 254 g' and b' flat occur as consecutive notes three times, holding the same position in the measures and making in the course of the three trials nine cases where g' overlapped b' flat. The lengths of these overlaps given in hundredths of a second are for S, 1st trial, 6-7-8; 2nd trial, 5-5-4; 3rd trial, 8-9-3; and for B 1st trial, 6-3-4; 2nd trial, 5-5-6; 3rd trial, 8-6-6. In like manner c'' precedes b' flat three times, the length of the overlaps being for S 1st trial, 7-5-5; 2nd trial, 4-4-5; 3rd trial, 3-4-5; and for B 1st trial, 6-5-6; 2nd trial, 5-4-5; 3rd trial, 6-3-3. From the comparison of a large number of cases it does not appear that the number of degrees of the staff intervening between any two successive notes affects to any appreciable extent the length of the overlap.

The average overlaps for the three repetitions of the different selections have been calculated, and are as follows:

TABLE XI.

Showing number and average length of overlaps in fractions of a second.

	S		B		M		W	
HYMN.	NUMBER.	AVERAGE LENGTH.	NUMBER.	AVERAGE LENGTH.	NUMBER.	AVERAGE LENGTH.	NUMBER.	AVERAGE LENGTH.
18	71	.044	80	.051	90	.064	63	.030
53	70	.043	78	.049	82	.057	72	.026
254	124	.050	130	.044	——	——	——	——
464	91	.048	97	.053	96	.050	——	——
516	——	——	——	——	152	.063	133	.031

As to the length of overlaps different subjects present different characteristics. M's average overlap in every case is twice as long as W's, which is shorter than that of any other subject. The kind of note in which a piece is written does not appear to affect greatly the length of the overlaps. Their average length in hymn 18, which consists mostly of half notes, is even less than it is in some cases where the selections are largely written in quarter notes.

It should be recalled that a note generally has two overlaps, being overrun by the preceding note at the beginning, and itself overrunning the following note at the end. From what has already been stated in relation to the small difference in the length of overlaps for long and short notes it is easy to see that in the case of notes of the larger denominations the length of the notes, minus their overlaps, is often proportionately greater than that of such small notes as eighths and sixteenths when similarly treated. It frequently happens with an eighth or sixteenth note that the part of the tone wholly free from overlaps is very small indeed. In the second measure of hymn 53 M gave to the first sixteenth note, the g', a total time of 0.18 sec., and for the sum of the overlaps at the two ends 0.13 sec., leaving only 0.05 sec. in which the note sounded alone. These figures represent the average of the three trials, and furnish an instance where the overlaps were exceptionally large in proportion to the length of the note. For the same note W, whose average overlaps are small, gave for the whole duration of the tone 0.14 sec., for the overlaps 0.05 sec., and for the time of the independent duration of the tone 0.09 sec., thus using but little over one-third of the time for the overlaps, and this is more nearly a typical case.

The tests in which all parts were played show in the soprano part the same characteristics as to overlaps as those in which the air alone was played. It is altogether likely that in playing all parts of a selection the tones in every part overlap one another in a manner similar to that in which they overlap in the air, though not necessarily to the same extent and at the same time. That this is true at least for tones struck simultaneously the records furnish some evidence. In those selections where all parts were played, several alto notes were of necessity recorded in connection with the soprano notes, but rarely did the tones in the two parts in such cases begin and end at the same instant. A few examples taken from the individual trials will suffice for illustration. In hymn 18,[1] second

[1] This hymn was transposed from the key of G to that of B flat. The tones here named are those found in the selection as it was transposed and played, the tones g', d', b' flat corresponding respectively to the tones a', e', c'' of the selection as it was originally written.

full measure, first note, the g' in the soprano was held by S 0.05 sec., and by M 0.12 sec. longer than the d'' in the alto. In the third full measure, first note, S held the b' flat in the soprano in one case 0.03 sec., and in another 0.08 sec. longer than the d'' in the alto, while B held the d'' in the alto 0.06 sec., and M 0.02 sec. longer than the soprano b' flat. In the sixth full measure, first note, W began the d'' in the alto 0.03 sec. before the g' in the soprano, while B began the soprano g' 0.01 sec., and S 0.02 sec. before the alto d''. The last note of the last triplet sounded longer than the d'' in the alto in different instances as follows: 0.04, 0.05, 0.09, 0.04, 0.07, 0.15 sec. For hymn 53 the records contain similar instances.

Results of Tests in which All Parts were Played.

As already mentiond Meumann has conjectured that the use of both hands in playing may result in greater precision in keeping the rhythm, and Ebhardt (*op. cit.*, p. 147) has found that the use of both hands quickens the general rate of execution. My own experiments furnish a certain amount of data on both points. Two hymns (18 and 53) were played by all the subjects, first as airs only, one hand being used, and then complete, both hands being used in the customary way. Each hymn was played three times as an air, and twice in the complete form.

General Rate.

The average time for playing the different selections was as follows:

Table XII.

Showing in seconds general rate when all parts were played.

	S	B	M	W
Hymn 18,	27.21	32.14	25.29	23.07
Hymn 53,	18.68	21.76	18.64	18.15

In hymn 18 the c' key was not connected with the writing magnet, hence the tone c' which occurs twice in the air of this hymn was not recorded, and the average time for playing the whole hymn is really larger than that given in the table by the time of two half notes. But even so if these times are compared with those required when the air alone was played (Table I, p. 39 above) it will be seen that in two cases more time was taken to play the selection when all parts were played. This is the reverse of Ebhardt's experience, and points to the need of further investigation of the matter with a view to discovering the effect of special conditions, and the range of individual differences.

The difference in the time of the two trials which the differ-

ent subjects gave each piece when playing all parts is expressed in tabular form as follows:

TABLE XIII.

Showing in seconds the differences in rate when all parts were played.

	S	B	M	W
Hymn 18,	.74	.87	1.62	2.91
Hymn 53,	.41	.15	.46	.59

A comparison of the two trials shows that in hymn 18 the second trial was the shortest and the first trial the longest every time, and in selection 53 the first trial is shorter three times and longer once. In case of hymn 18 there is thus a contradiction of what was found in this regard where only the air was played.

The Measures.

The average length of the measures is larger than where the air only was played, and necessarily so since the total time is greater.

TABLE XIV.

Showing in seconds the average duration of the measures.

	S	B	M	W
Hymn 18,	3.52	3.99[1]	3.25	3.28
Hymn 53,	3.12	3.59	3.12	2.82

The following table gives the greatest variation between any two successive measures occurring in the individual trials. The figures in smaller type below each number represent, as in the case where the air alone was played, its value as a percentage of the correspondiug average measure in the preceding table.

TABLE XV.

Showing in fractions of a second the greatest variation between any two successive measures in the individual trials.

HYMN.	S	B	M	W
18	.30 8.5	.19 4.8	.24 7.4	.23 7.0
53	.32 10.3	.15 4.2	.16 5.1	.27 9.6

[1] B presents here the same characteristic as was observed where the air alone was played (see foot note, p. 41), namely, that of making a very long interval at the end of the first half of the selection (the middle of the stanza). If this interval, which is .56 sec. long, is added to the preceding note according to the regular method of treating intervals then the length of the measure within which it falls is 5.21 sec. Reckoning in this measure the length of the average measure becomes 4.19 sec.

For the most part these differences are larger than when the air only was played; in case of subject B alone are they smaller. The average irregularities are as follows:

TABLE XVI.

	S	B	M	W
Hymn 18,	.095	.108	.108	.121
Hymn 53,	.155	.090	.080	.204

If these irregularities are compared with those for the same hymns when the air alone was played it will be found that the irregularities are on the whole somewhat greater when all parts are played.

The deviations of the individual measures from the average measure present the same general characteristics as when the air alone was played, but there is frequently a lack of correspondence in the signs of the deviations in the two ways of playing. The variations are also considerably larger where all parts were played. The deviations in connection with the fourth measure in hymn 18 are all plus, and show that the measure was retarded by all the subjects. The first half of the stanza ends within this measure, and it is within this measure, also, that the transition takes place from one line of the score to the next lower. In hymn 53 there is one set of deviations in which the signs are all minus, and one in which they are all plus, traces apparently of a tendency to begin each line of the verse or phrase of the music rapidly and then to retard. This is clearer in the trials with all parts than where the air alone was played.

The Notes.

The following table gives the average length of the different kinds of notes that are found in hymns 18 and 53 where all

TABLE XVII.

Showing in hundredths of a second the average length of the notes where all parts were played.

HYMN.	SUBJECT.	HALF.	DOTTED QUARTER.	QUARTER.	EIGHTH.
18	S	88		44	
	B	100		52	
	M	82		42	
	W	77		42	
53	S	119	75	51	26
	B	120	88	60	30
	M	98	87	53	18
	W	——	72	49	26

parts were played, and is to be compared with Table VI, p 43. In finding these averages all doubtful[1] notes were excluded.

A study of the relative values of these notes shows just as great variations as are to be found when the air alone was played. So far as can be judged from the half and quarter notes there is a tendency here to shorten the longer notes and lengthen the short ones In hymn 18, for example, when the average half note in the tests with all parts is compared with two average quarter notes S made the half note equal, B 0.04 sec. shorter, M 0.02 shorter, and W 0.07 shorter than two quarter notes. When only the air was played S made the half note 0.05 sec. longer, B 0.04 longer, M equal, and W 0.01 longer. A like comparison of the notes in hymn 53, where comparison is possible, presents similar relations.

Special Cases.

Triplets. The triplet groups in hymn 18, so far as the records could be used, present no striking differences from those in the same hymn when the air only was played. B, M, and W in the first triplet connected the first note with the preceding half note, thus making it impossible in case of these subjects to ascertain the whole duration of this triplet or the value of the first note. In all cases the last note of the triplet was given more time than the second. A similar characteristic was noted where the air alone was played. (See p. 44.) S, B, and M made the second note of the last triplet shorter than either of the others, while W made it longer than the first and shorter than the third. The variations here do not correspond in their relative positions with those that occurred where the air alone was played, and they are upon the whole somewhat larger.

Eighths and Sixteenths. The last half of the second measure of hymn 53 was more irregular in the tests with all parts than when the air alone was played. In all cases the part of the measure containing the combination of dotted eighths and sixteenths exceeds the amount of time given to the other half. The excess for the different subjects is as follows: S 0.11 sec., B 0.10 sec., M 0.07 sec., W 0.05 sec. The difference here is greater than when the air only was played as may be learned by referring to page 44. This relative lengthening of the shorter notes in the "all parts" playing is in harmony with the tendency already noted in the section on the notes, though the case is not entirely clear. Comparing these elements with the average of the quarter notes in the first half of the measure

[1] Occasionally an alto note was recorded in connection with a soprano note. In such instances the length of the note could not be determined with absolute accuracy.

we find that S and M made the eighth notes proportionately too short, and the sixteenths too long, while B showed a strong tendency to make both kinds of notes too long, and M was equivocal. Both B and M gave the second sixteenth note, that is, the tone *b'* flat, no separate individual existence. This was true for both subjects in each of the trials. The tracings show that the second eighth note, or tone *a'*, overlapped the third eighth note, or tone *c''*. In the case of B this overlap was 0.03 sec., and in the case of M it was 0.04 sec. The tone *b'* flat appears to have been played at the same time as tone *c''*, beginning with it and ending before it. It is quite possible that in playing these notes the two keys were touched at the same time, the *b'* flat key being fully depressed and the *c''* key only partially so until after the *b'* flat tone had received its full time, when the *b'* flat key was released and the *c''* key fully depressed. But the partial depression of the *c''* key was sufficient to cause it to sound and to give a record. This explanation seems to be verified by the great length of the *c''* tone for both subjects, which is not very different from the combined length of the first dotted eighth and sixteenth notes, that is, tones *a'* and *g'*.

Accent.

In the selection where all parts were played the conditions are not favorable for determining what is true in regard to the relative length of the accented and unaccented notes. The subjects in accordance with instructions played in their habitual way. Three of the subjects in playing two or more notes that followed one another consecutively on the same degree of the staff depressed the key but once, keeping it down for a time equal to the duration of the whole group of notes. It was impossible to determine the value of other notes because with the means used for recording they were not separated from notes preceding or following them in the alto part. In hymn 18 note *c'* was not recorded at all. Subject S (hymn 18) gives the only cases in which the records can be used for this purpose. The results have already been given on page 45. They show, like those where the air alone was played, that the accented notes had a somewhat longer duration than the unaccented ones.

General Summary of Results.

Throughout the experiments there is a wide range of "personal difference."

When there was no intervening pause, or only a short one, there was in most cases a considerable variation between any two successive executions of the same selection. In such instances the smallest difference in general rate for any subject

and for any selection is .17 sec., and the largest 2.74 sec. The tests indicate that a musician in playing a selection a second time is more likely than otherwise to play it at a slower rate than he did the first time, provided there is no pause, or only a short one, between the two performances.

The variations of the measures, also, are not constant. The difference between any two successive measures is frequently larger than 0.2 sec., while on the other hand it is often as small as 0.01 sec. There are, however, only three cases where the average irregularity amounts to 0.1 sec. The general irregularity is greater in the last half of the selections, but this is probably due to the terminal retardation.

The relative lengths of the tones were also variable, and do not follow exactly the ratios represented by the written notes. They were sometimes too great and sometimes too small.

A comparison of the triplets with the note occupying the other unaccented position shows that the chances were about equal as to whether a triplet was given too much or too little time. There was, however, a slight tendency to make the second note of the triplet longer than the first, and a strong tendency to make the last longer than either of the others.

In two of the selections containing such combinations of notes as to make determinations in regard to accent possible, there is a marked lengthening of the accented notes. In the other selection this characteristic is not present.

Intervals occur between successive notes on the same degree and on different degrees of the staff. Those of the latter sort are comparatively few, and, with the exception of those coming at the end of verse lines, are very short and probably accidental. When an interval occurs the preceding note is usually shortened and the length of the measure is not affected to any great extent. The number of overlaps is large; their length is far from uniform; and, like that of intervals, does not depend upon the length of the notes involved. In case of such small notes as eighths and sixteenths only a small proportion of the tone is without overlaps. The records indicate that in playing all parts of a selection the tones in every part overlap one another.

The results of the tests with all parts may be summarized as follows: The subjects executed hymns 18 and 53 with no greater accuracy when all parts were played than when the air alone was played. In some ways the results show a greater lack of exactness. The tempo is no better observed, the measures show a greater want of uniformity, and the errors in making the length of the tones of the different denominations are as large and as numerous. Meumann's hypothesis of a motor appreciation aiding the musician in his execution of the frac-

tional parts of intervals is probably not far wrong, but my results do not support his conjecture that in playing with both hands one aids the other in giving to time intervals their correct relative lengths.

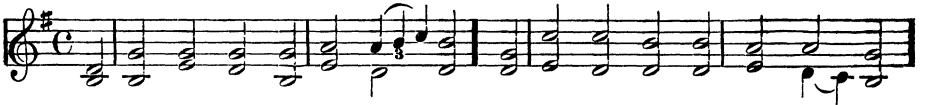
Below is given the scores of the selections that were played in the experiments.[1] In each case the average time values of the notes for the different trials are given in hundredths of a second.

Hymn 18 was transposed from the key of G to that of B flat because of the special tuning of the instrument, and played from the manuscript score.

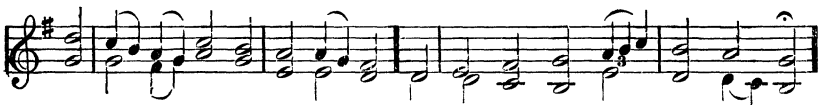
Air alone played.

18 All praise to Thee, my God, this night. L. M.

T. TALLIS.



S.	84	90	87	90	81	90	21	28	30	90	85	93	76	97	82	94	79	81
B.	91	96	91	95	89	84	25	24	40	89	86	93	89	96	85	92	84	201
M.	83	78	70	73	66	77	23	25	26	72	71	76	69	77	70	75	70	75
W.	68	73	67	72	65	74	19	20	28	71	73	73	68	73	65	73	68	76



S.	88	38	42	39	48	85	87	90	40	39	89	90	88	80	85	22	27	31
B.	88	46	44	43	45	95	94	94	42	42	91	98	91	97	94	27	25	41
M.	73	39	36	38	39	74	71	73	35	33	73	75	75	77	69	27	29	28
W.	70	36	34	34	35	70	68	66	34	35	71	71	71	74	67	22	22	29

S.	90	90	154			
B.	96	94	194			
M.	77	80	87			
W.	70	76	177			

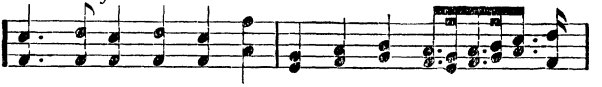
Air alone played.

Christmas

53 Shout the glad tidings, exultingly sing. P. M.

SECOND TUNE.

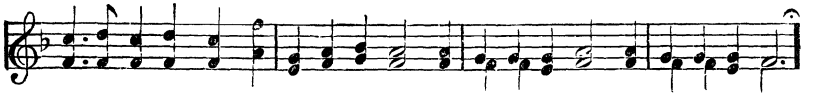
Chorus after the last verse.



S.	79	22	50	52	52	51	53	53	48	32	18	32	15	39	18			
B.	82	23	47	51	55	53	50	51	51	41	9	34	18	39	19			
M.	75	22	52	50	52	53	52	53	49	41	10	38	16	38	14			
W.	72	15	44	44	43	43	43	45	43	29	13	31	12	29	17			

[1] For the electrotypes used, the writer is indebted to the courtesy of the Century Co., from whose Edition of the Hymnal the music was taken.

53.—Continued.



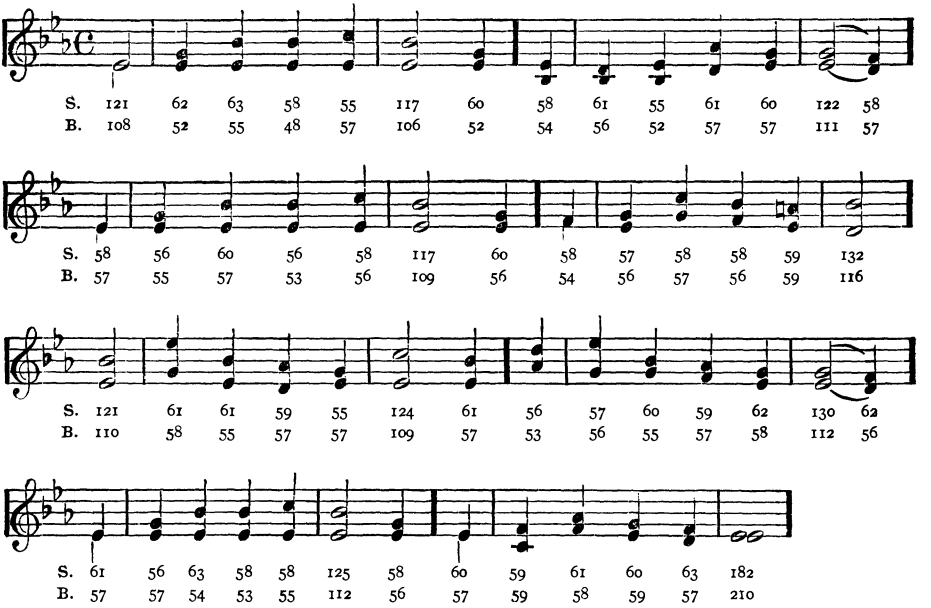
S.	81	22	49	51	51	50	52	49	54	111	46	57	52	48	110	47	57	53	53	129
B.	77	23	49	53	52	54	50	52	54	106	55	56	59	52	113	56	58	59	57	142
M.	77	25	49	48	51	52	51	52	51	101	53	57	50	50	101	56	55	50	53	146
W.	62	16	39	43	43	44	43	43	46	96	45	49	48	45	96	46	52	48	48	208

Air alone played.

254 From Greenland's icy mountains.

7.6. D.

DR. LOWELL MASON.



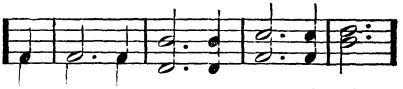
S.	121	62	63	58	55	117	60	58	61	55	61	60	122	58
B.	108	52	55	48	57	106	52	54	56	52	57	57	111	57
S.	58	56	60	56	58	117	60	58	57	58	58	59	132	
B.	57	55	57	53	56	109	56	54	56	57	56	59	116	
S.	121	61	61	59	55	124	61	56	57	60	59	62	130	62
B.	110	58	55	57	57	109	57	53	56	55	57	58	112	56
S.	61	56	63	58	58	125	58	60	59	61	60	63	182	
B.	57	57	54	53	55	112	56	57	59	58	59	57	210	

464 The spacious firmament on high.

D. L. M.

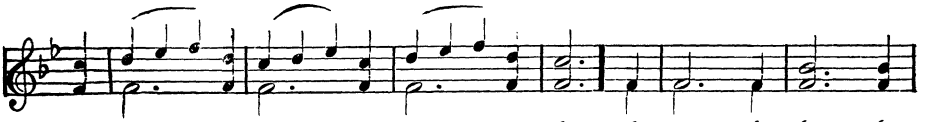
HAYDN.

Air alone played.

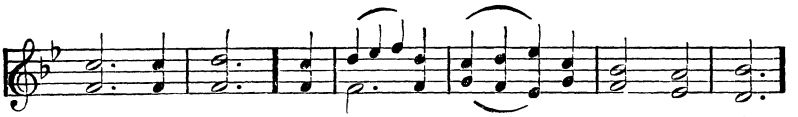


S.	54	152	50	154	47	151	48	156
B.	62	162	55	159	54	159	56	160
M.	38	102	31	106	31	102	32	98

464.—Continued.



S.	50	51	51	49	51	51	50	51	52	50	47	54	52	165	56	154	46	161	46
B.	54	55	55	57	54	55	54	53	55	54	50	59	56	163	58	165	56	162	59
M.	38	35	34	35	33	34	35	32	37	32	34	33	34	93	38	104	32	105	34

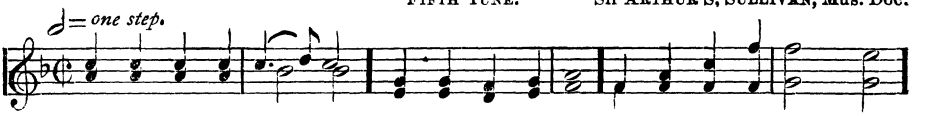


S.	149	52	164	52	54	49	50	53	52	52	52	54	114	114	160				
B.	163	57	162	54	56	54	58	55	55	51	53	57	112	110	162				
M.	99	34	93	33	34	34	37	30	33	33	32	35	63	69	79				

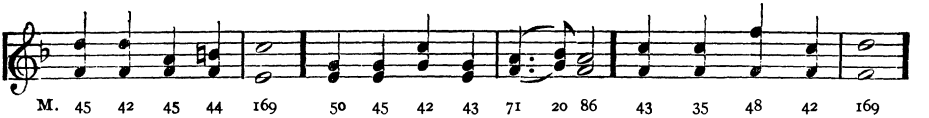
516 Onward, Christian soldier.

6.5.

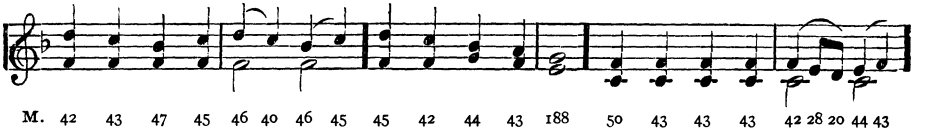
Air alone played. FIFTH TUNE. Sir ARTHUR S, SULLIVAN, Mus. Doc.



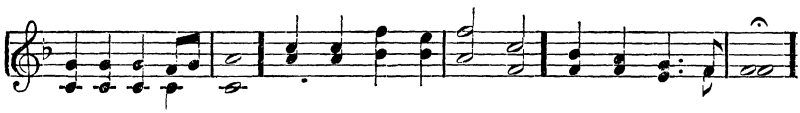
M.	51	45	43	43	68	17	76	46	42	43	43	168	64	43	43	44	85	84	
W.	48	49	45	46	70	19	82	46	39	44	42	128	41	42	40	44	82	85	



M.	45	42	45	44	169	50	45	42	43	71	20	86	43	35	48	42	169		
W.	45	37	43	43	136	45	39	41	40	58	18	75	42	36	43	37	126		



M.	42	43	47	45	46	40	46	45	45	42	44	43	188	50	43	43	43	42	28 20 44 43
W.	37	38	40	38	40	37	39	38	40	37	36	41	143	44	40	41	40	38	21 20 40 39

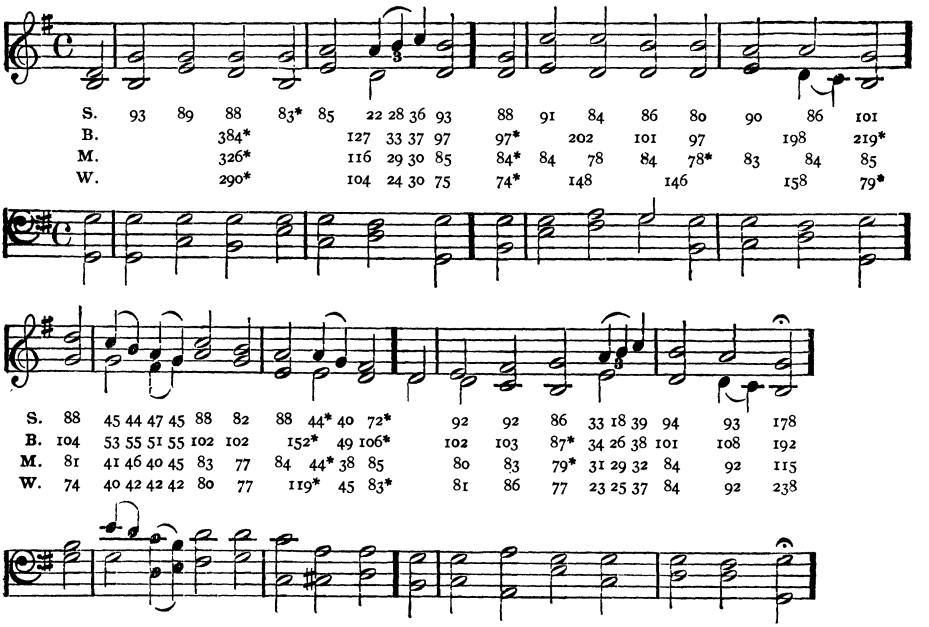


M.	47	42	44	22	22	174	49	41	47	44	89	82	45	45	70	31	149		
W.	42	42	36	20	21	146	45	39	41	44	86	82	46	46	71	23	157		

All parts played.

18 All praise to Thee, my God, this night. L. M.

T. TALLIS.



S.	93	89	88	83*	85	22	28	36	93	88	91	84	86	80	90	86	101
B.			384*			127	33	37	97	97*		202		101	97	198	219*
M.			326*			116	29	30	85	84*	84	78	84	78*	83	84	85
W.			290*			104	24	30	75	74*		148		146		158	79*

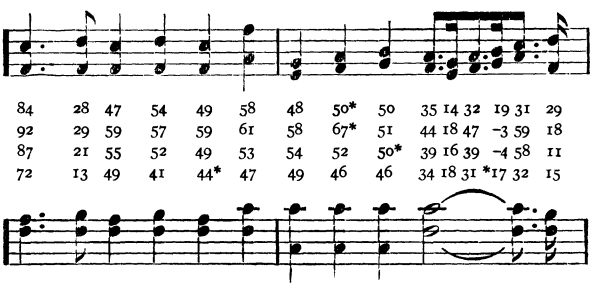
S.	88	45	44	47	45	88	82	88	44*	40	72*	92	92	86	33	18	39	94	93	178
B.	104	53	55	51	55	102	102	152*		49	106*	102	103	87*	34	26	38	101	108	192
M.	81	41	46	40	45	83	77	84	44*	38	85	80	83	79*	31	29	32	84	92	115
W.	74	40	42	42	42	80	77	119*		45	83*	81	86	77	23	25	37	84	92	238

All parts played.

Christmas

53 Shout the glad tidings, exultingly sing. P. M.

SECOND TUNE.

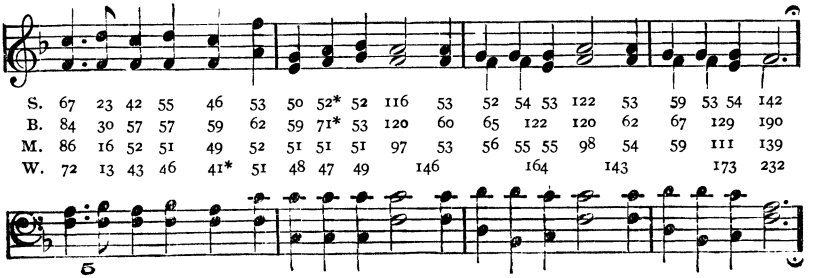


S.	84	28	47	54	49	58	48	50*	50	35	14	32	19	31	29
B.	92	29	59	57	59	61	58	67*	51	44	18	47	−3	59	18
M.	87	21	55	52	49	53	54	52	50*	39	16	39	−4	58	11
W.	72	13	49	41	44*	47	49	46	46	34	18	31	*17	32	15

*The exact length of a starred note is doubtful owing to the fact that in being recorded it was not separated from the preceding or the following alto note.

The duration of the whole group of notes is given in cases where two or more notes follow one another consecutively on the same degree of the staff, and where the subject depressed the key but once for the whole group.

53.—Continued.



S.	67	23	42	55	46	53	50	52*	52	116	53	52	54	53	122	53	59	53	54	142
B.	84	30	57	57	59	62	59	71*	53	120	60	65	122		120	62	67	129		190
M.	86	16	52	51	49	52	51	51	51	97	53	56	55	55	98	54	59	111		139
W.	72	13	43	46	41*	51	48	47	49		146			164		143		173		232